Physics-Based Stability and Control Derivative Measurement (PSCDM)

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Purpose

New developments in high-aspect ratio wings (structural efficiency) and quiet low-speed performance (aerodynamic efficiency) for next-generation aircraft require a change in measurement/control paradigm to robustly, effectively address the range of maneuver and nominal/off-nominal flight conditions. Conventional approaches using global air data and structural feedback will need to be augmented to improve gust load alleviation and circulation control to autonomously and intelligently sense the aerodynamic environment and efficiently adapt the aircraft structure and control surfaces to suit the current mission objectives. This project will develop a localized system that (1) separates aerodynamic forces and moments into a circulatory and non-circulatory component, and (2) estimates and controls each component independently along span stations.

Effectively, this system re-derives the conventional stability and control (S&C) derivatives, where the circulatory and non-circulatory components are focused on the aerodynamics and structural dynamics, respectively. This approach is enabled by the unique combination of (1) the ability to track in real-time surface flow topology, e.g., leading-edge stagnation point or flow separation, (2) the analytical relationship of the spatiotemporal surface flow topology to circulation, and (3) the ability to measure total inertial response. Phase 1 investigates the effectiveness of the new approach in separating/estimating circulatory and non-circulatory forces for S&C derivatives. Phase 2 will extend the results to a fixed wing aircraft (Area-I's PTERA: Prototype - Technology Evaluation Research Aircraft) and a flexible wing vehicle (X-56A) implementing circulation- based robust aeroservoelastic control.

Background

Flow bifurcation point sensors will be used to estimate - in real-time without the delay of structural response - circulatory components of aerodynamic forces and moments which could be used as direct aerodynamic force feedback for circulation control, and accelerometers to estimate the total non-circulatory component of aerodynamic forces and moments. Sensors are integrated in a physics-based architecture that improves reliability, control effectiveness and robustness through a spatially distributed network. This research effort will provide for the first time an in-flight separation and estimation of circulatory and non-circulatory components of aerodynamic forces and moments enabling fine-scale circulation and aeroservoelastic control.

The National Aeronautics R&D Plan describes concepts that could be separated into two parts: (1) monitoring technology: structurally integrated sensors, distributed sensing systems, physics- based transition prediction, and aircraft-level health-management; and (2) control technology: actively controlled wing structures, novel flow control techniques, and advanced flight controls for aircraft efficiency. The proposed system, once validated, will help satisfy the above needs with a physics-based embedded sensor architecture distributed across the wing span.

This effort provides a foundation for control of sub/tran/supersonic aircraft, including UAVs and long- endurance platforms, using intelligent sensing with distributed control methodology. Demonstration with a previous system has shown potential on an AFRL SensorCraft configuration in the NASA Langley Transonic Dynamics Tunnel. This work will provide the basis for transitioning the architecture to platforms such as X-56A and other potential flight test platforms for circulation control with aeroelastic or novel flush aerodynamic sensing experiments.